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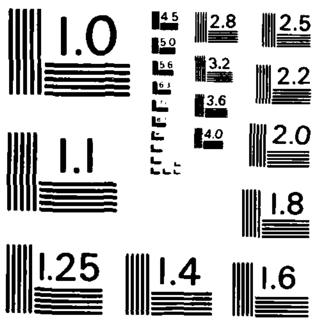

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL REPORT
DRI #2652

1? November 1974

REPORT

AD-A148 243

P-STATIC STUDY

UNIVERSITY OF DENVER • DENVER RESEARCH INSTITUTE

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DRI #2652

TECHNICAL REPORT

P-STATIC STUDY

Contract No. N00019-74-C-0334
Phase I

- Submitted to -

Naval Air Systems Command
Washington, D.C. 20360
Attention: A. D. Klein, AIR-360G

- Submitted by -

Electronics Division
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1. INTRODUCTION

The work effort ~~performed in this phase~~ of ~~the~~ contract consisted of a study of all likely sources of static electrification on aircraft and/or missiles which may lead to electromagnetic radiation. ~~In~~ fact, it was intended that the study should be general enough to include other airborne objects as well for the purpose of identifying other possible static electrification phenomena not considered pertinent on aircraft or missiles. For example, possible static electrification on satellites were studied. Nothing of interest for objects other than aircraft and missiles were found that appeared to produce any significant radiated energy. The emphasis of this study was to identify expected radiated electromagnetic signals and the source which creates the most attention for initial study.

The initial efforts consisted of a literature search to obtain information about the history of research as well as the current research being conducted in this area of interest. A summary of the literature search which was performed can be found in the DRI Quarterly Report for the period 5 March 1974 to 5 June 1974.

Laboratory measurements of corona discharge were made to provide guidelines for searching the literature to determine characteristics of radiated energy due to static electricity discharge. A discussion of the results obtained from these measurements can be found in the DRI Quarterly Report for the period 5 June 1974 to 5 September 1974.

This report is intended to be a review of the findings of these studies conducted during Phase I along with recommendations (based on these findings) for continued work under Phase II.

2. INVESTIGATION OF AIRCRAFT

As discussed in the Interim Quarterly Report for the period 5 June 1974-5 September 1974, the primary sources of static electrification on aircraft are:

a. Corona discharge;

b. Streamer discharge, and

c. Charge acquisition in a antenna region due to the impact of individual particles.

The first two sources were found to be the only sources which might result in significant electromagnetic radiation. Streamer discharge was found to be a secondary interest because it rarely occurs in clear air, is hard to distinguish from atmospheric energy radiations from storm cells (where streamering does exist), and since preventive techniques exist which eliminate this source during most atmospheric conditions encountered in aircraft flight. However, corona discharge was found to exist for nearly all flying conditions; therefore, the continuous presence of this source of static electrification, along with a repeatable waveform shape of PRF on the order of 10^5/sec. that is predictable, rendered it of considerable interest. As a result, more detailed investigations were made to determine the nature of electromagnetic radiation expected from this source.

The frequency of interest for radiation from corona discharge is in the bandwidth 10 MHz to 200 MHz (this will be discussed in more detail later). Therefore, this spectral bandwidth is of interest for more detailed investigation in Phase II.

Once the corona discharge source was identified to be of definite interest, an investigation was conducted to identify other possible sources not mentioned in the literature. This investigation consisted of an attempt to obtain empirically any radiated signals from aircraft in the frequency

spectrum below the one of interest mentioned above. Since it was not known what signal shape to expect in the time domain, steady-state frequency measurements were made. The three separate frequency ranges considered are:

a. 10 Hz to 300 Hz (ELF);

b. 5 kHz to 1 MHz (VLF-LF), and

c. 3 MHz to 30 MHz (HF).

Figure 1 shows a block diagram of the equipment used to make the ELF measurements. Observation of the oscilloscope display during the absence and presence of low flying aircraft constituted the data measurements in the ELF band. The measurements were made very close to (often, directly beneath) the aircraft flying at an altitude of approximately 100 feet. The observed signal due to the presence of an airplane appeared to be a sinusoidal signal of about 10 Hz with an approximate amplitude of 50 mv/meter. The fundamental and harmonic components of 60 Hz from power lines produced a measured background signal of approximately 100 mv/meter and if higher ELF frequency components were radiated bby aircraft they were not discernible in this background signal. Since this 10 Hz signal was observed from aircraft only when they were very near to the receiving antenna, it is concluded that the obtained measurement was due to the static field of the aircraft and would not produce useful signals at any appreciable distances. However, for early investigations of nearby aircraft this signal may be useful for triggering recording devices used in the study under Phase II.

Figure 2 shows a block diagram of the equipment used to make the VLF-LF measurements. The oscilloscope was used to observe signals in the time domain while the frequency selectable voltmeter was used to monitor 3 kHz bandwidth measurements. The center frequency could be varied from 5 kHz to 1 MHz. Attempted measurements were of aircraft flying at an average

altitude of 500 feet. The average line-of-sight distance from the aircraft to the antenna was 1200 feet. Although some impulsive activity could occasionally be seen above the noise background during an airplane fly-by, the same type of activity could be seen during the absence of aircraft as well. No steady-state increase could be seen. Also, the AM radio frequency broadcasting stations presented such a strong background signal that virtually no conclusions can be made concerning electromagnetic radiation from aircraft in this bandwidth.

Figure 3 shows a block diagram of the equipment used to make the HF measurements. The loop antenna was placed in the same location as the VLF-LF whip antenna. Again, no increase in the steady-state level was noticed from the envelope detector during aircraft fly-by. The presence of impulsive noise always seemed to be present during an aircraft fly-by for frequencies above 20 MHz whereas during the absence of an aircraft the impulsive noise was not always present. This observance may be purely coincidental however, since it was impossible to monitor any one frequency setting for more than a few aircraft fly-bys in order to make measurements over the entire frequency range.

This investigation indicates that if any electromagnetic radiation does exist in the bandwidths considered, it is of smaller amplitude than the average background noise level. Since there is nothing in the literature which presents specific time-dependent waveform shapes consisting of these frequency components (except streamer discharge), it is difficult to define more involved measurements in these frequency bands. The conclusion is to maintain the initial interest in corona discharge.

3. INVESTIGATION OF MISSILES

Although the charging mechanisms present in missiles vary from those in aircraft, the discharge mechanisms are nearly the same. One exception is that the exhaust plume of the missile may serve as a discharger (rather than a charger) at certain altitudes. This is because missile exhaust leaves a net positive charge on the missile, while tribo-electric charging leaves a net negative charge on the missile. Therefore, at altitudes where tribo-electric charging can occur, the exhaust plume tends to neutralize or discharge the missile.

The primary discharge of static electricity appears to be corona discharge. As with aircraft, proper techniques essentially eliminate streamer discharging. Therefore, the conclusion again is that it seems of interest to study corona discharge since it also exists on missiles a great deal of the time that a missile is in flight.

As mentioned above, the rocket motor exhaust, or plume, serves as both a charger and a discharger, the particular function being altitude dependent. The result is an altitude dependence of potential (and thus, electrostatic charge) on the missile. Figure 4, which illustrates this, was encountered while reviewing the available literature.[1] This figure triggered an interest in missiles that are fired from aircraft since prior to a firing such a missile must be maintained at the same potential of an aircraft. Nanevicz[2] et al have shown that even aircraft with dischargers

1 J.C. Axtell and T.C. Oakberg, "An Electrostatic Charge Phenomenon Associated with Minuteman Missile Flights," Lighting and Static Electricity Conf., December, 1968.

2 J.E. Nanevicz, E.K. Vance, R.L. Tanner, G.R. Hilbers, "Development and Testing of Techniques For Precipitation Static Interference Reduction," SRI Final Report, Project 2848, Contract #AF-33(616)-6561, January 1962.

this mechanism may be desirable.

Another area of interest may be that of missile operation above the ionosphere. If the missile contains a net charge at this altitude, then upon re-entry into the ionosphere, glow discharge may occur which could produce significant electromagnetic radiation.

4. PROPERTIES OF CORONA GENERATED ELECTROMAGNETIC RADIATION

Due to the fact that corona discharge exists on aircraft for nearly all flying conditions, and on missiles for many flying conditions, a more involved investigation was conducted to determine the characteristics of resultant radiated energy.

The actual physical process involved in negative point corona discharges consists of a complicated sequence of events. However, the overall influence of the disturbance has been investigated in the laboratory. Tanner[3] et al indicate that the total current pulse due to corona discharge at sea level occurs in approximately 200 nanoseconds, with a rapid rise time of approximately 10 nanoseconds. Varying the geometry or the atmospheric pressure appears to affect the total duration time of the pulse but not the rise time. The pulses which occur vary slightly in amplitude and duration due to small local differences in geometry, and atmospheric conditions. However, assuming these differences to be small, Figure 5 is a representative average pulse shape of a corona discharge. This is the waveshape of the interfering signal often encountered at the receiving antenna of aircraft, since the antenna is in the "static" zone of the corona discharge region. The normalized frequency spectrum for this pulse is shown in Figure 6. This spectrum agrees very well with the spectra obtained from laboratory measurements of an aircraft trailing edge by Tanner and Nanevicz[4]. Most of the work dealing with corona discharge has been with spectra of this type.

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3 R.L. Tanner, "Radio Interference from Corona Discharges," SRI Technical Report, Contract #AF-19 (604)-266, April 1953.

4 R.L. Tanner, J.E. Nanevicz, "An Analysis of Corona-Generated Interference in Aircraft," IEEE Proceedings, Vol. 52, January 1962.

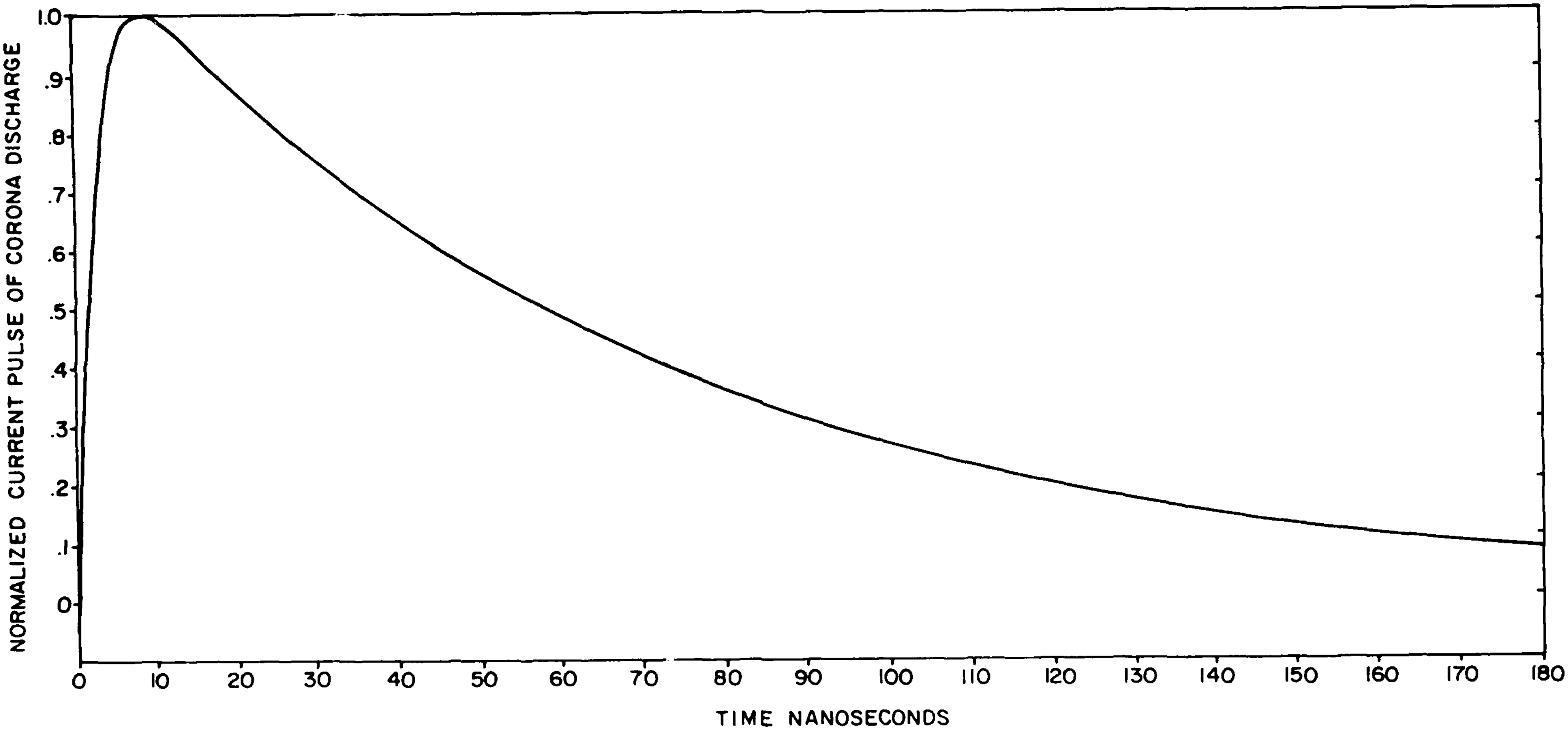

FIGURE 5. CURRENT PULSE OF CORONA DISCHARGE

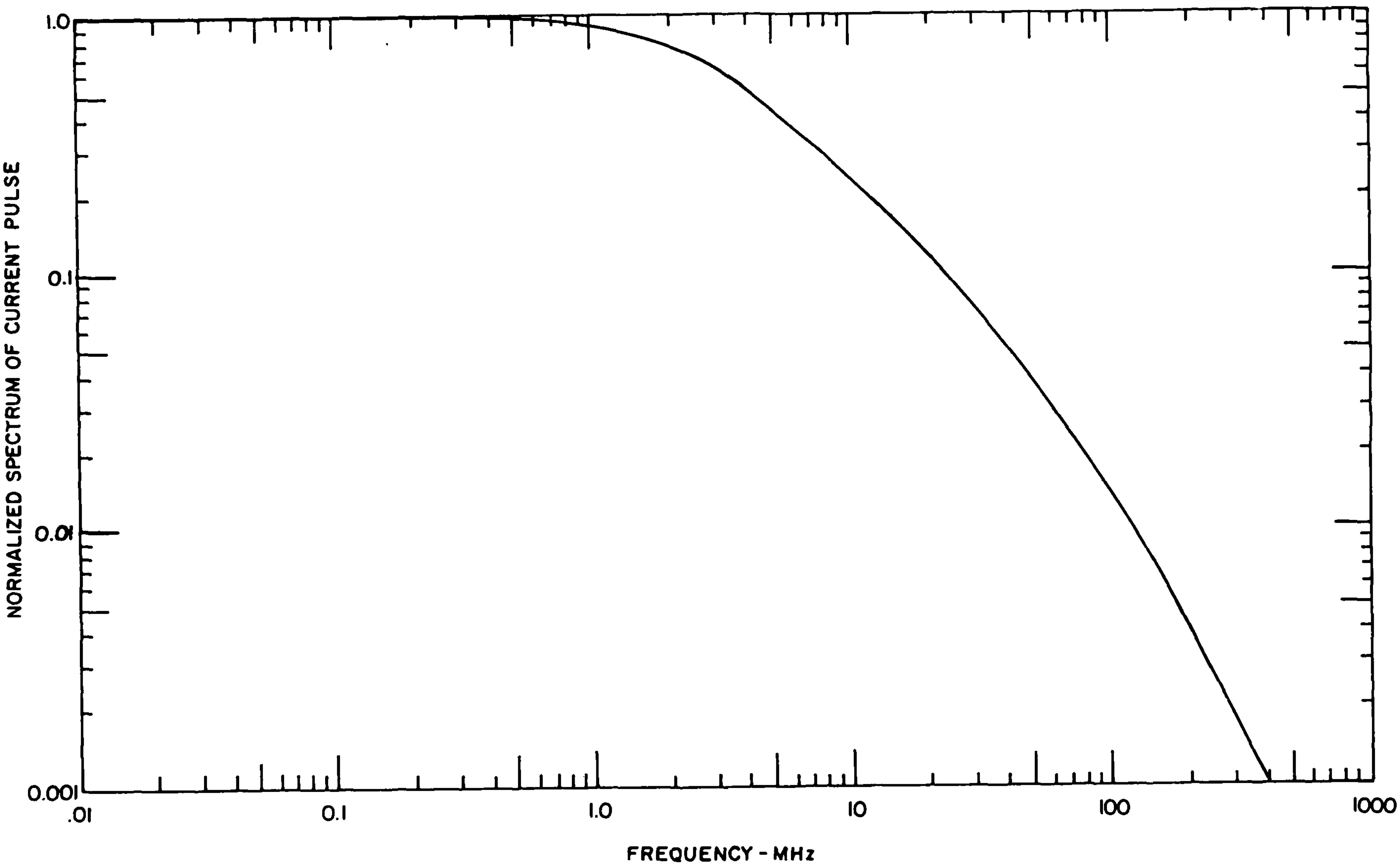

FIGURE 6. FREQUENCY SPECTRUM OF CURRENT PULSE FROM CORONA DISCHARGE

The radiated electromagnetic signal that would be realized from this current pulse in a region away from the "static" zone of the corona discharge region (i.e., the "radiation" zone) is shown in Figure 7. Also, the normalized spectrum of such a signal is shown in Figure 8. The frequency region containing the most energy is from 2 MHz to 200 MHz. If the bandwidth 10 MHz to 200 MHz were considered, the impulsive characteristics of Figure 7 would be maintained. Only the slowly varying negative region of the signal would be altered.

Since this impulsive shape is repeatable for all corona discharge, it is possible that special techniques can be developed to "pick" these signals out of the background noise. Such techniques are especially desirable if the background noise does not contain impulsive characteristics at these frequencies. For example, assume the time function present at a receiving antenna to be

$$f(t) = n(t) + m(t),$$

where $n(t)$ is the background signal and $m(t)$ is the signal due to a corona discharge. Suppose $f(t)$ is applied to some system operator K at the input of a receiving system, so that

$$x(t) = K[f(t)]$$

is the output of this operator. Also, define $p(t)$ and $q(t)$ to be

$$p(t) = K[n(t)], \text{ and } q(t) = K[m(t)].$$

If K is a linear operator, then

$$x(t) = p(t) + q(t),$$

and the goal of defining K would be to minimize $\bar{p}(t)$ and maximize $q(t)$. To realize this goal, both $n(t)$ (the background noise in the vicinity of the receiver) and $m(t)$ (the signal due to corona discharge) must be known. The bandwidth of $m(t)$ illustrated in Figure 8 is of interest for the following reasons:

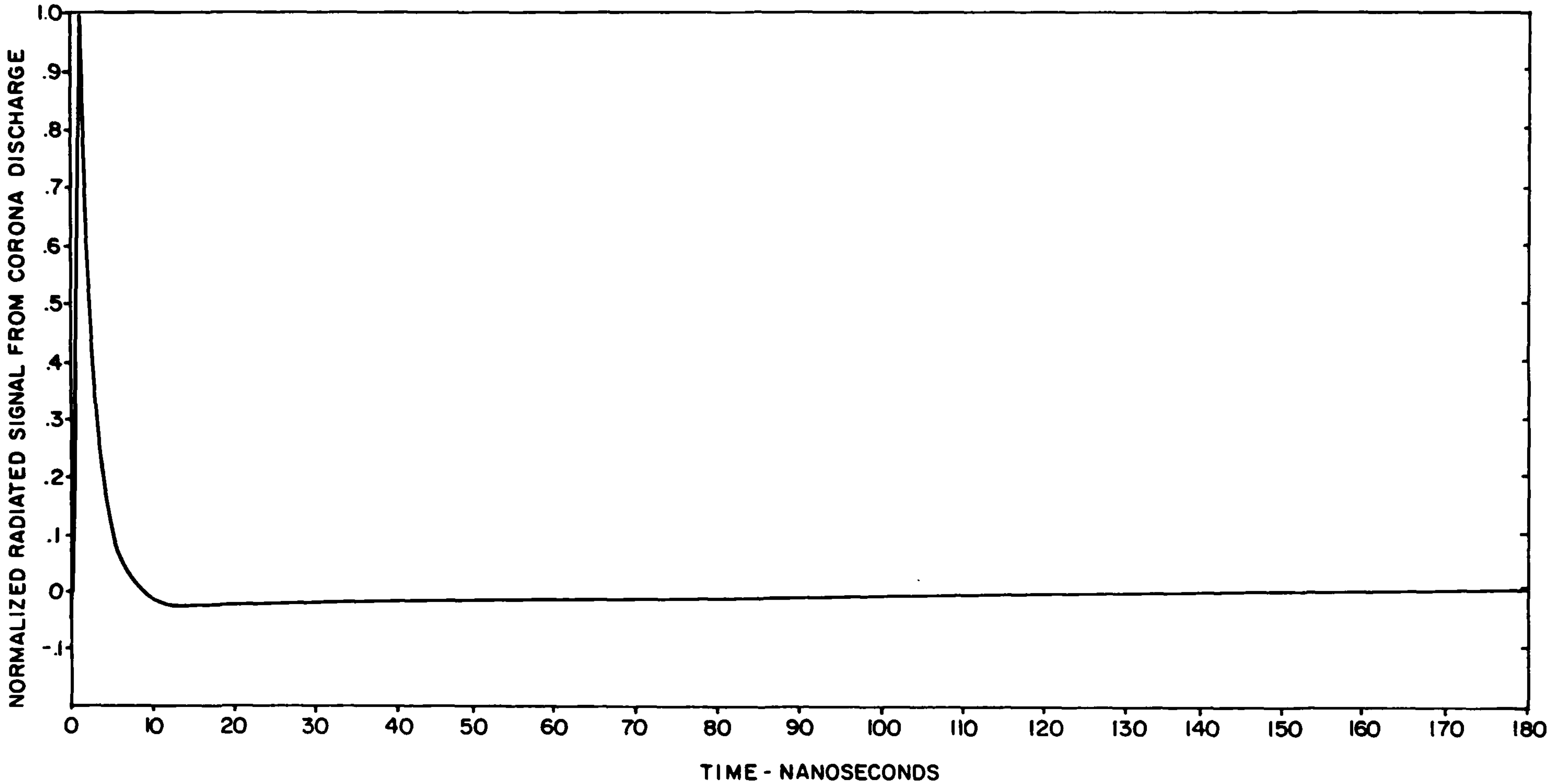

FIGURE 7. RADIATED SIGNAL FROM CORONA DISCHARGE

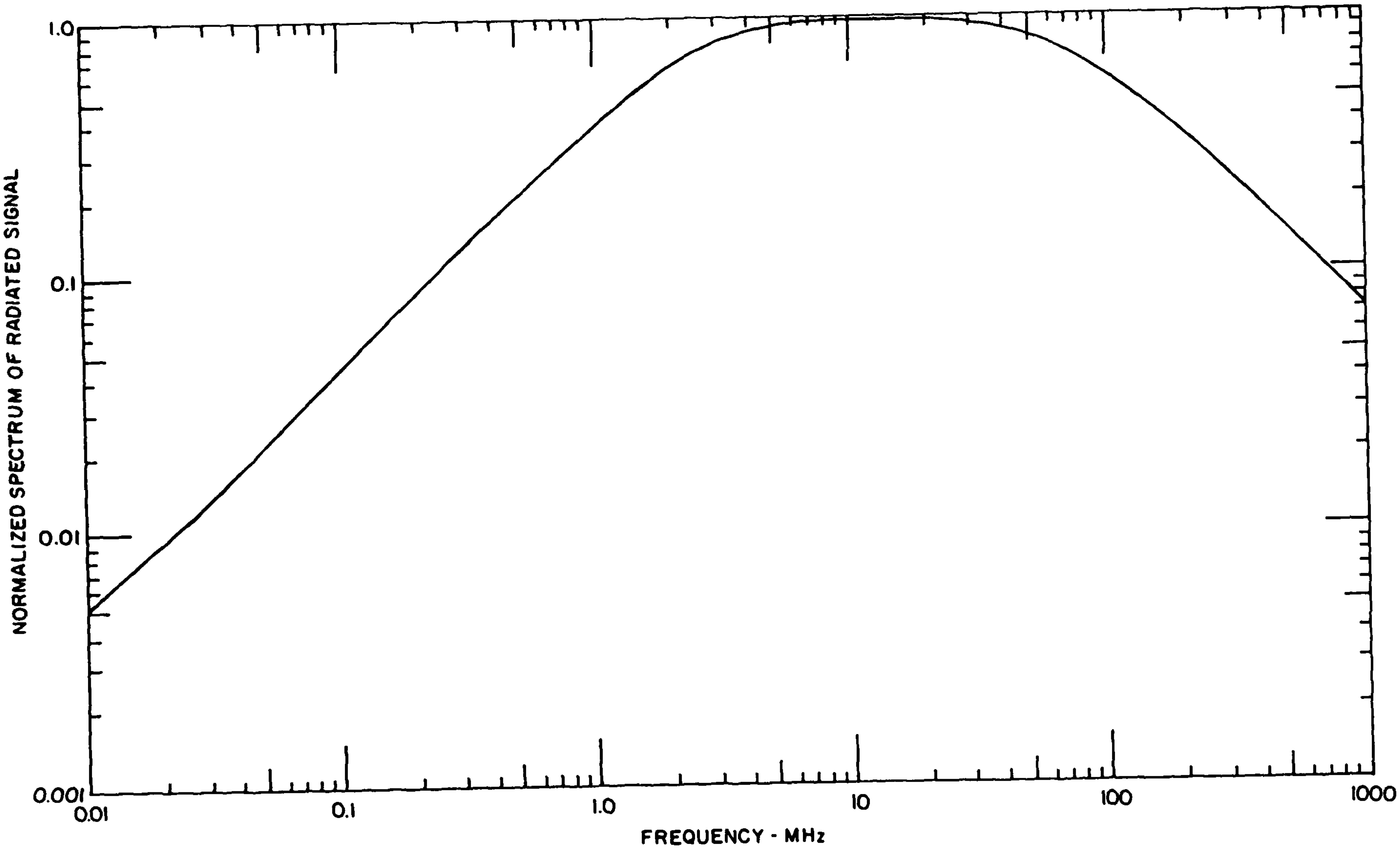

FIGURE 8. FREQUENCY SPECTRUM OF RADIATED SIGNAL FROM CORONA DISCHARGE

a. The lower end of the bandwidth is above the frequencies of the AM broadcast band and other sources, such as signals due to lightning discharges.

b. Frequencies above approximately 25 MHz are not reflected by the ionosphere so that background noise energy that would create impulsive shapes such as the early time interval in Figure 7 (i.e., approximately 20 nanoseconds) must be due only to sources local to the receiver.

From this it can be seen that part of the operator K would consist of a high pass filter whose lower cutoff frequency could be equal to or greater than 2 MHz (the actual value would probably have to be determined experimentally). The remaining composition of the operator K would then depend on the nature of the background noise in the locality of the receiver, as well as the impulsive shape of the radiated signal from corona discharge.

Due to the fact that corona discharge is a source of radiated energy due to static electrification which is always present, a concentrated study to determine the operator K seems highly desirable.

5. RECOMMENDATIONS FOR PHASE II

Due to the findings during Phase I of this contract, it is recommended that the following tasks be undertaken in Phase II. Since it may not be possible to realize the fulfillment of all these tasks with the budget and time period available, it is suggested that the order of precedence for each task be in the same order as they appear, unless further knowledge at a later date would indicate otherwise.

Task I - Investigate the possibility of measuring radiated signals from corona discharge by the proper determination of a linear operator at the input of a receiving system. Such a study would require an investigation of background noise in the location of the proposed receiver site and a measurement of the waveshape of an actual signal radiated from a corona discharge fro. aircraft to corroborate the theory.

Task II -Investigate streamer discharge effects on military aircraft due to the existence of large plastic radomes not commonly present on commercial aircraft.

Task III - Investigate the static electrification effects on a missile that is launched from an aircraft.

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